U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

WASATCH NATIONAL FOREST

ALTA AVALANCHE STUDY CENTER

Miscellaneous Report No. 12

SNOW AND AVALANCHE CONDITIONS AT MT. BALDY, CALIFORNIA

Des F. Rady
Area Director
Mt. Baldy Recreation Area
Angeles National Forest

September 1966

Preface

The winter recreation area of Mt. Baldy, situated at 34° 20' N. latitude on a sharp topographic divide between coastal climate and desert, presents some unusual snow, weather and avalanche conditions.

The snow ranger's task of insuring public safety on this part of the Angeles National Forest is compounded by the proximity of the huge Los Angeles metropolitan center, most of whose residents are totally unfamiliar with mountain snow hazards.

The peculiar conditions prevailing at Mt. Baldy are an excellent example of the necessity for modifying avalanche forecasting and control procedures to fit local climate. They also illustrate a severe problem in public relations.

In the following report Mr. Rady has summarized his problems and methods of dealing with them. This can be read with profit by ski patrolmen and snow rangers everywhere who are charged with responsibility for public snow safety. It is gratifying to present this valuable addition to the accumulating record of climatic influence on snow and avlanches.

E. LaChapelle
Avalanche Hazard Forecaster

TERRAIN & ASPECT

The Mt. Baldy Recreation Area is located at the north extremity of San Antonio Canyon on the Angeles National Forest. The snowplay area consists of a narrow canyon bottom (southwest exposure) with steep rising sides (50 to 90 degrees), extremely rocky, and sparsely covered with mixed brush and timber. Approximately $\frac{1}{4}$ mile to the north, these same canyon walls on the east side are utilized by the Mt. Baldy Ski Area as part of the ski trail system.

Elevations range from 6500' at the bottom of #1 (Sugarpine) lift, up to 8500' at the top of #3 (Thunder Mt.) lift. The headwall of San Antonio Canyon, which forms an east to west saddle (elev. 7800'), is also the divide between the Mojave desert and ocean drainages.

Distance in air miles from Baldy Notch to the valley floors to both north and south is approximately 10 miles. The above mentioned saddle, or divide, at Baldy Notch is bordered by Mt. San Antonio (elev. 10,080') to the west, and Thunder Mt. (elev. 8500') to the east. Alternate canyons, or faces, emptying from these elevations into San Antonio Canyon, constitute the majority of hazardous slide paths, since they ultimately reach the #1 lift line, or the snowplay area.

WEATHER

Either the desert or ocean dominates the Mt. Baldy weather; at times there is a violent clash of the two. A definite weather pattern can be traced. The desert, or north influence, most common in fall or early winter, is often in the form of strong gusty "Santa Ana" winds. Gusts up to 90 miles per hour have been recorded at Baldy Notch. This is a warm

wind, comparable to the Chinook winds of the eastern Rockies. Temperatures rise very sharply. Records indicate that a rise of 30 degrees in a 24 hour period has occurred in mid-winter. Also, being a desert wind, the Santa Ana is extremely dry. Relative humidity readings of less than 5% are not uncommon. The most disastrous brush fires in this region are associated with this wind. Studies on actual moisture lost from snow packs to this wind would produce some interesting answers. Observations indicate a wind cycle duration of two days, and seldom more than five days, with the rise in temperature most evident on the second day (See Fig. III & V).

A south, or ocean influence, on the other hand, is normally associated with damp cool weather, and so far without exception is the route of approaching storm fronts. Winds from this direction seldom exceed 20 miles per hour. With the exception of the spring months, temperatures normally drop or stay constant. Since this exchange of influence is dependent on the position and movement of high and low pressure systems, a standard barometer can be an important forecasting tool.

The daily weather map, published in the local paper, is an excellent source of information. In contrast to the north wind cycles, storm periods, or intensities, do not show an indication of a pattern. They vary from a one-day sprinkle to two weeks of torrential precipitation.

As far as the storm periods themselves, some notes of interest are as follows:

Major storm periods, throughout the winter months, seem to favor temperatures between 23 and 28 degrees. Most storm periods will have temperatures near or above the freezing point either at the

beginning or the end. (See Fig. I) Prolonged overcast (south influence) at the end of storm period is often accompanied by rising temperature, as long as overcast persists, and at times light rain. Clearing skies, (particularly if clearing occurs at night) often mean a sharp, short drop in temperature. The advent of such sudden clearing is at times marked by short, violent thunder storms, representing the clash of north and south influence. Although temperatures drop when the skies clear, if the north influence persists, a sharp rise can follow in 48 Hours. Usually, it is this post-frontal activity of the storm system that is responsible for troublesome rain crust or tapioca at the top of the pack, which forms an undesirable old snow surface for future layers.

SNOW TYPES (See Figure II)

The most important single feature in the pattern of deposited new snow types is the presence of graupel, or pellet snow, in almost all new snow layers.

Snow densities are high and parallel with the high prevailing storm temperatures. Overnight low temperatures may drop to 10-20 degrees. However, daytime temperatures, even during storms in mid-winter, are often above the freezing point. It is not uncommon to have mixed rain and snow in mid-winter. The result is stratification of graupel, rain crust, slush, snow types of lighter density, or even what might be considered powder, due to difference in day and night temperatures. The graupel will vary in size from a pin point to $\frac{1}{4}$ in. diameter. Such a layer persists in

the snow pack for extremely long periods of time. It defies metamorphism and tends to freeze into crust layers. It often creates air pockets either underneath or internally. These graupel layers, loose or crusted, often hold the key to determining depth of possible fractures, and are second only to the old snow surface as a contributing slide surface. Powder snow, such as associated with powder skiing, has not been common at Mt. Baldy recently. However, with sufficient depth (24' plus), snow with densities up to 0.09 has provided satisfactory "powder skiing." The highest densities recorded have been new snow in the form of large crystals.

SNOW METAMORPHISM

Two factors deserve notice in relation to metamorphism in our snow pack. The first of these is the effect of erratic temperature fluctuations. For example:

> Late March, or even April in the last three years have brought our deepest new snow deposits. Temperature prior, and immediately after these storms, which deposit their snow near the freezing point, have ranged near 60 degrees.
>
> The second influence is that of the ground temperature itself. More often than not, these late snow packs are deposited on warm ground, particularly of southern or southwestern exposures, such as Hocomoc Canyon. (See Fig. VI).

This can produce several complications, even in comparatively deep packs such as the 5' pack of April 1965, in a matter of days. For example:

Accelerated Metamorphism

Percolation of free water

Air pockets

Depth hoar

The last two might bear explanation. Regarding the air pockets, their location will vary according to factors involved. If ground temperature is warm, particularly if new snow is deposited on bare ground, air pockets tend to form at the ground-snow interface. If a crust or ice layer is present in the snow pack, and if this layer is strong enough to support subsequent layers, the layers immediately below this crust will have a tendency to settle away from the crust. This has been found to be common, particularly if the snow type under the crust is recently deposited large crystals and had not had time to undergo metamorphic change prior to the crust formation on top of it. For example:

A rain crust formation at the end of one storm cycle, immediately followed by another with additional new snow. The air pockets themselves will vary greatly in size; from very small to 2'' high by 12 to 16'' in diameter under crust layers, and up to 4'' high at ground surface.

At times these pockets have been numerous enough to leave less than 50% of the layer surfaces bonding. The inner surfaces, or walls, of these pockets are mostly very uneven. Within the snow pack they are composed primarily of chunks of semi-frozen crust, easily crumbled by hand, at the ground surface the appearance is the same, but samples of the cavity walls crumble into slush when touched.

The very rapid formation of depth hoar has been observed, again in the case of new snow on warm, bare ground. Often this phenomenon will precede the above-mentioned formation of air pockets. The structure itself is extremely wet and soft. Crystals are large, 3 to 4 milimeters; they seldom attain the full cup shape of mature depth hoar, but tend to melt into slush or freeze into an easily crumbled uneven crust layer prior to maturity.

During Santa Ana conditions, or periods of north influence, particularly in early spring, settlement and ablation rates can be extremely high. As much as 50% of the pack can disappear in one day. Free water at ground level is common with this condition. (See Fig. IV) However, due to the extreme dryness of this type of wind, it can be assumed that some of the moisture from the snow pack is lost to the atmosphere.

AVALANCHE FACTORS

The picture thus presented is, for the most part, harmonious with that outlined for the Pacific Coast by LaChapelle (1965), with the following accentuation according to local observations to date:

> Avalanche activity is confined almost entirely to direct action, with slides running during, or within 48 hours after each storm. Major contributing factors are raincrust layers or layers of consolidated graupel. Both characteristic ingredients of the local snow layers are caused by the often extreme, sharp rise in temperature following storms. Sun-ball action or direct rain serve as triggers.

Old snow layers with persistent high prevailing temperatures as a rule tend to stabilize quickly and settle through metamorphism. Thus

climax avalanches are not common. Old snow packs, after 6 to 10 days of mild weather usually can be considered completely stable. These will tend to serve as a future slide surface rather than be involved in any climax activity. This has been observed to be true even with a depth hoar layer at ground level, air pockets in the pack, or internal layers of ice.

Wind, sometimes inhibits avalanche danger. Since our strong north winds blow after clearing, their warming effect accelerates settlement and metamorphism. They scallop the old snow surface to allow new snow layers to form a bond, and due to their strength and speed carry unconsolidated snow downslope, rather than build up cornices or unstable cushions on canyon walls. Storm winds from the south are usually comparatively gentle. They tend to pack the new snow rather than to build up dangerous unevenness.

HAZARD FORECASTING

Avalanche hazard forecasting consists primarily of:

1. Tracing, in the local newspaper weather map, clouds or warm fronts, and low and high pressure areas, in relation to north or south influence.
2. The observation of storm intensities at localities prior to the frontal passage, such as rainfall figures up the coast in Los Angeles, Santa Barbara, etc. and the consequent clearing at these areas prior to local clearing.
3. Close observation of the temperature curve, if possible, to determine direction of heat exchange.

4. Also close observation to determine the moment of the inevitable change in air flow from south to north, or the reverse.
5. Determining the type of old snow surface at all release zones, density and volume of new snow, together with new snow types and specific stratification of the new layers; particularly telltale ice or graupel layers.
6. Checking total new snow depth and densities against past slide histories to determine times of critical instability.

INSTRUMENTATION

Instruments for these necessary observations can be comparatively simple. At the time of this writing, few of our tools are of commercial manufacture.

Three specific observation sites have been set up. The first is at Baldy Notch (elev. 7800') on the divide between ocean and desert influences. Its primary function is to gather data in the upper accumulation zones, and to detect first indications of a change in direction of air movement. At present a wind sock, made of silk on wire hoop, on a removable mast, indicates wind direction. The standard annommeter proved unsatisfactory due to icing during heavy fog.

The wind sock can be removed during foul weather, and used only for periodic checks. Overflow cans from a standard rain gauge are used to compute water content of new snow fall. Core samples can be collected from the storm stake, the contents melted by immersing the can in a two gallon bucket partially full of hot water, and the ratio computed from reading the depth on storm total stake.

Snow stakes, cut from 1 x 2 redwood, are fastened to 1" upright pipe, set in concrete during previous summer. This fastening down is necessary due to the high winds. The total accumulation stake is fastened permanently, while storm total and hourly stakes are free to slide up or down along said pipe, with a hinged platform on the bottom to allow observer to slide the stake straight up out of the snow, and then place the platform down on the pack again.

During periods of low overcast, temperature of the cloud cover can be determined at this station. Recording instruments, such as precipitation gauge, etc., would be a welcome addition at this station, since access during a storm is sometimes difficult. Standard maximum and minimum thermometers provide essential temperature information.

Snow profile pits (discussed later), dug near this station, allow strata observations near the release zones. Test skiing is also done near this elevation.

The second site is at the 6500' level, utilizing the roof of the #1 lift as an instrument platform. The loft of the same building serves as office, file room, and central gathering place for all snow data. This station is kept in operation when the other two become inaccessible due to the weather. It was put in operation during the 1965 and 1966 season, primarily to provide comparative data betweeen the notch station at 7800' and the bottom of slide paths at 6500'.

Instruments are much the same as the Notch station, with instruments on the roof and snow stakes on the flat below. A hygro-thermograph is located in a shelter on the roof to facilitate close observation of the temperature curve, particularly to forewarn of any warming trends at this elevation.

A standard barometer is used to trace the movement and variations of low and high pressure systems. A large aerial photo, with clear plastic overlay, is used to record slide occurrence, location, date, time, class, etc. with grease pencil. A separate overlay shows slide history and patterns.

The third observation site is the Mt. Baldy Ranger Station. It is located 5 miles south of station #2 at 4200' elevation. Primary function of this station is the observation of barometric pressure, to forewarn of weather fronts. Also, through the courtesy of the County Flood Control, we have a recording precipitation gauge, readings of which give warning of high precipitation intensities sometimes before they occur at the ski area to the north. Since we are tied in on U.S. Weather Bureau radio network, accurate weather forecasts are received daily on the station radio. The daily newspaper, delivered here, provides weather maps which are helpful in determining what type of influence we might expect.

SNOW PROFILES

Snow profiles and studies consist primarily of stratigraphic pits at the release zones at Baldy Notch (7800') and occasionally at station #2 (6500'). Pits are dug at level, exposed area, walls are brushed with soft paint brush to bring out strata, and samples of the strata are examined with small magnifying glass for classification as to type and metamorphic stage.

A ram-penetrometer could be used here to classify layer hardness. Thickness of layers is measured with upright yard stick or snow stake. Layer temperatures are measured with photo lab dial thermometers, and

densities are calculated from samples taken with individual beer cans, with cut out tops. (Plastic lids for these are available at any supermarket). Color tread profiles have not been successful to date, due to the shallowness of layers. These simple profiles have been very helpful in determining proximity of slide surfaces, or structural weakness in new layers. However, since metamorphism is very active in our warm climate, profiles have to be taken every 24 hours, especially during or after storms, to detect and identify problems in time. As indicated by our avalanche patterns, these observations and analysis are most critical during and after storms.

AVALANCHE CONTROL

Control measures are also most critical during and after storms. The most practical of these has been ski stabilization during storms, followed by closure of the area if snow fall intensities and volume prove this to be ineffective.

The use of explosives is a very touchy situation. First, the deposition zone of most slide paths is the lift line of #1 lift itself. Although threatened towers have slide diversion mounds, even relatively small slides can inactivate the lift, which represents the only access from the parking lot of the ski area and back. Consequently its function is necessary as long as any part of the ski area is in use. In addition, the lift line itself finally channels into the parking lot. There is also the possibility of sympathetic slides in the snow play area below. Thus the only safe time to use explosives is at night when the entire area is empty.

As far as the type of explosives; to date only hand placed charges have been attempted. Any remote firing would have to be done over the top of, and extremely close to the #1 lift. A dud of any type (such as it is often the case with the avalauncher) could be disastrous if found by one of the 700,000 annual visitors to the area. Ski and foot stabilization, done by the Ski Patrol or lift employees, has been our most effective control measure. However, the ultimate decision of when this method is no longer effective, during any given storm, has to be made and closures put in effect. This of course constitutes a very undesirable situation, since closures in this area are extremely difficult to maintain, particularly after the storm clears. It often requires armed deputies, since several hundred snowplayers per acre is not unusual. Our closure signs range from 4 x 8 foot sheets of plywood, painted international orange with 6" black letters, to portable signs, 4 x 2 feet with 4" letters, mounted on 8 foot metal posts too big to carry off in a car.

At permanent closures, where the area is completely uncontrolled, these signs are linked by rope netting barriers. However, even these drastic measures are not 100% effective, since visitors can reach the area in less than 1 hour from downtown Los Angeles and find it completely impossible to realize that avalanche hazard could exist in Southern California. Consequently we have set up two rescue caches, complete with probes ($\frac{1}{2}$" thick walled, aluminum electric conduit), shovels, lights, rescue procedure outline, etc. One of these is at the Baldy Notch, and the other is at the snowplay area.

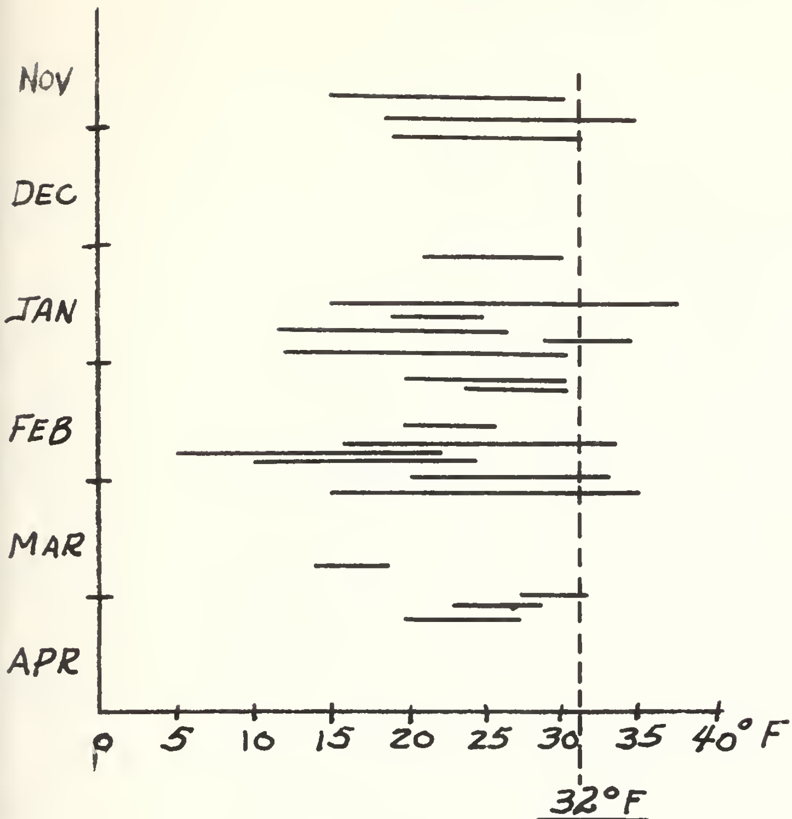
Training and rescue practice sessions are held every year, both in the summer and during actual snow and ice conditions. Participating in

these sessions are all the agencies normally involved in rescue operations, such as the Forest Service, Ski Patrol, County Sheriffs personnel, and Ski lift employees. The primary purpose of these sessions is a common understanding of procedures, and familiarity in working together. The rescue operation of April 1965 was an example of practical application of the groundwork from these sessions.

CONCLUSION

Possibly the most persistent detriment to our snow study program is monotony, for heavy snow winters are infrequent and past avalanche problems have been few and far between. However, as outlined in the above text, all the contributing factors for such problems are present, and the hazard increases every year in parallel with our rising recreation use figures. A wide range of experimentation in control measures, refinement of theories through observation and analysis, and certainly an opportunity for self-training are open to the efforts of any future snow ranger who is inclined to answer the challenge.

FIG. I

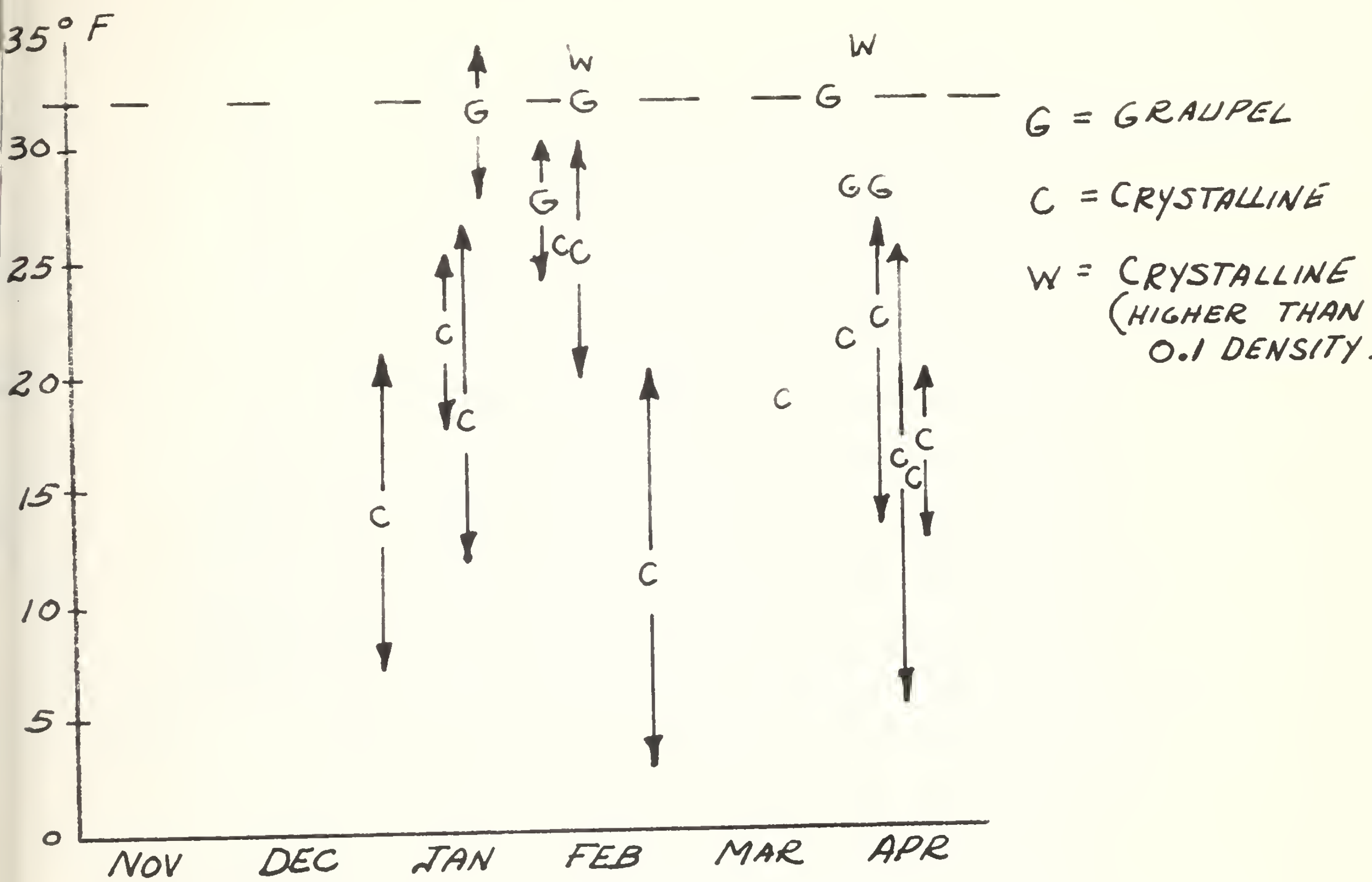


OBSERVATIONS OF AIR TEMPERATURE VARIATIONS DURING MAJOR STORM PERIODS

(BALDY NOTCH - ELEV. 7800')

(OBSERVATION PERIOD: 1955, 56, 64, 65, 66)

FIG. II

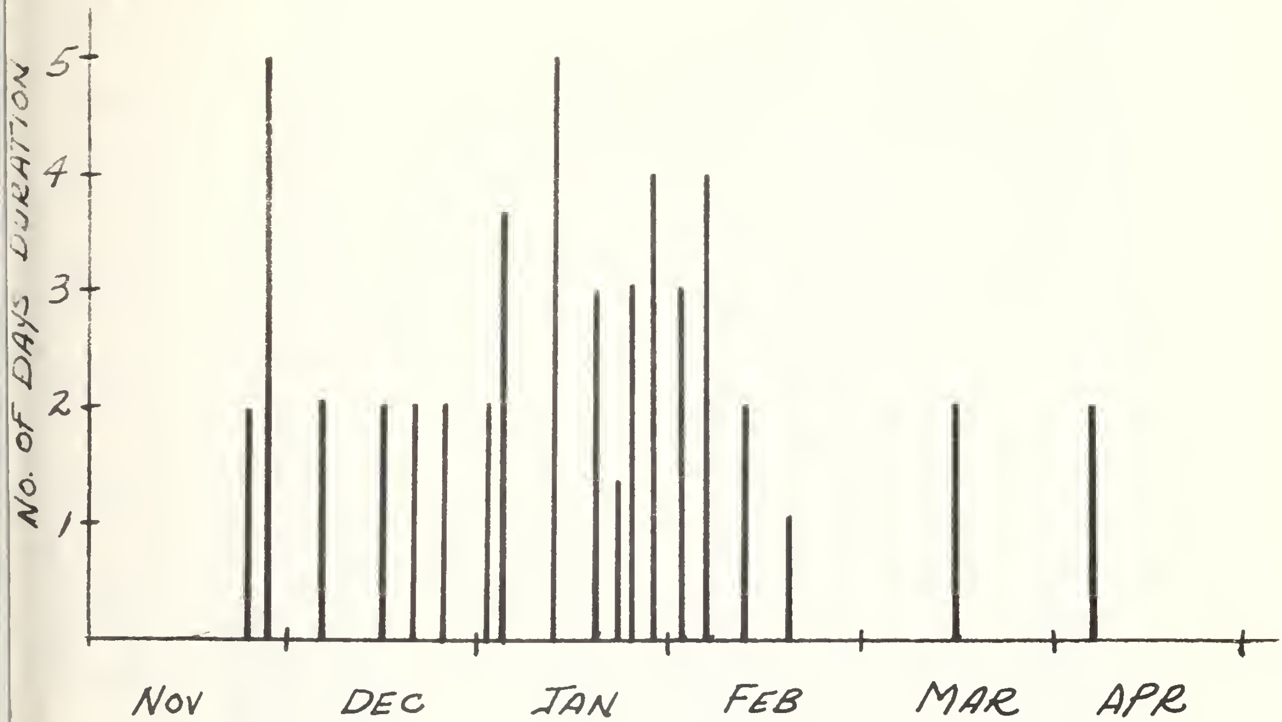


NEW SNOW TYPES OBSERVED AT VARIED AIR TEMPERATURES

(MT. BALDY NOTCH - ELEV. 7800')

(OBSERVATION PERIOD: 1955, 56, 63, 64, 65, 66)

FIG. III

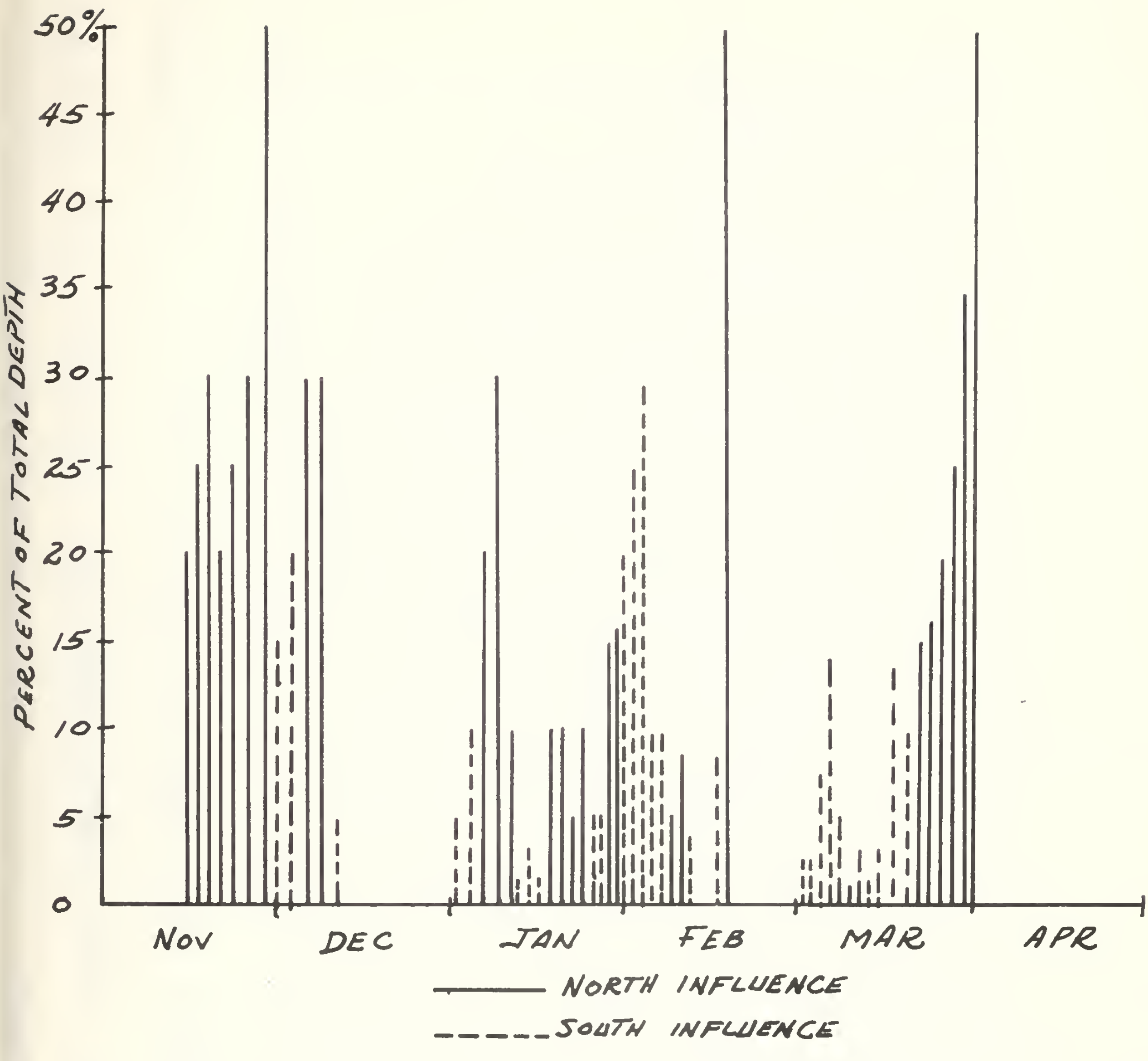


OBSERVATIONS OF DURATION OF NORTH WIND CYCLES.

NOTE: OBSERVATIONS MADE ONLY DURING SNOW PERIODS – CONSEQUENTLY THIS GRAPH HAS NO BEARING ON FREQUENCY OF CYCLES – ONLY DURATION.

(OBSERVATION PERIOD: 1955, 56, 61 THROUGH 66)

FIG. IV

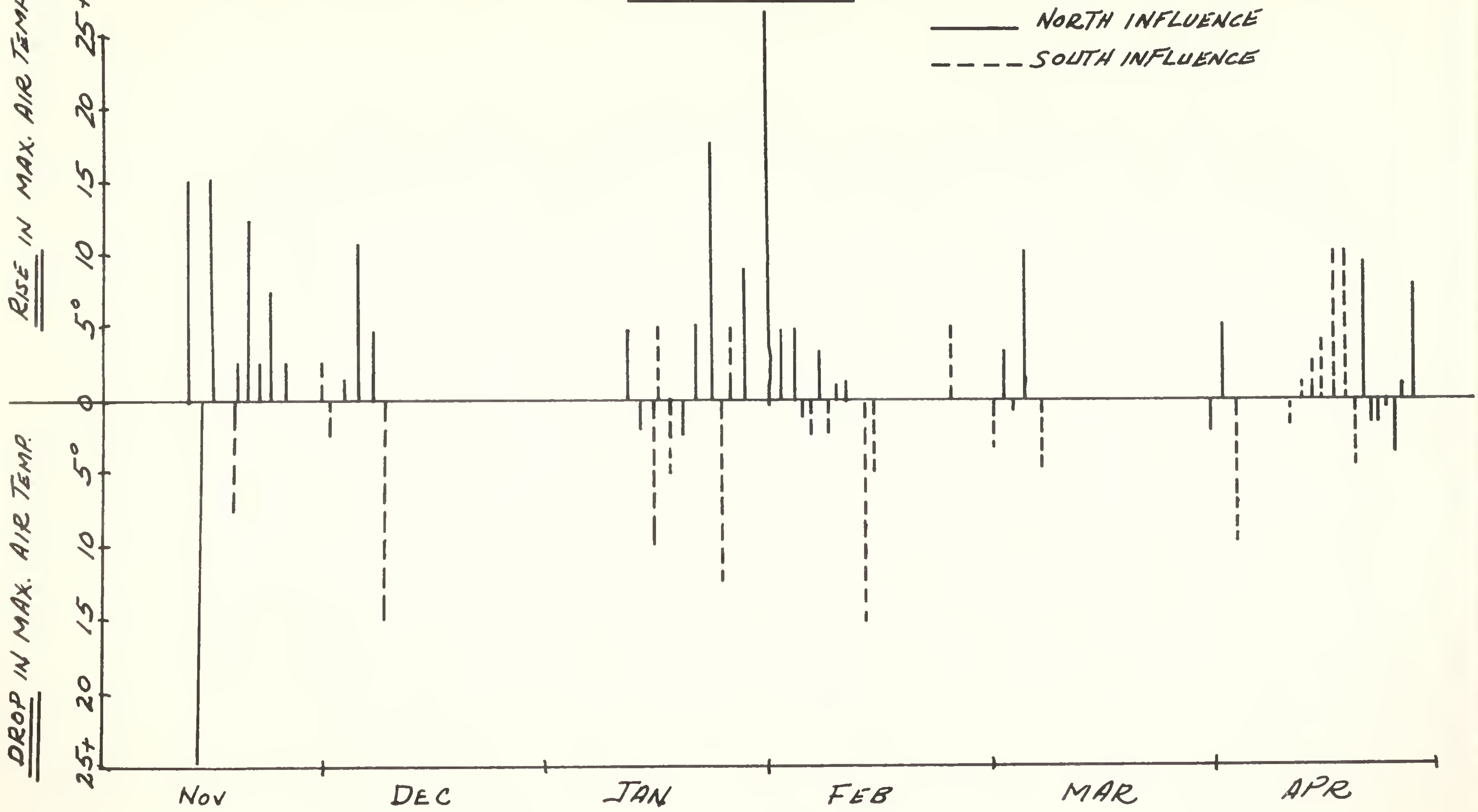


OBSERVATIONS OF SURFACE DEPRESSION IN PERCENT OF TOTAL DEPTH PER 24 HR PERIOD, AS INFLUENCED BY NORTH, OR SOUTH INFLUENCE (AIR MOVEMENT)

(MT. BALDY NOTCH – ELEV. 7800')

(OBSERVATION PERIOD: 1955, 63, 64, 65, 66)

FIG. V



OBSERVATIONS OF FLUCTUATION OF MAX. AIR TEMPERATURE IN 24 HR. PERIODS, AS AFFECTED BY NORTH, OR SOUTH INFLUENCE

(MT. BALDY NOTCH - ELEV. - 7800